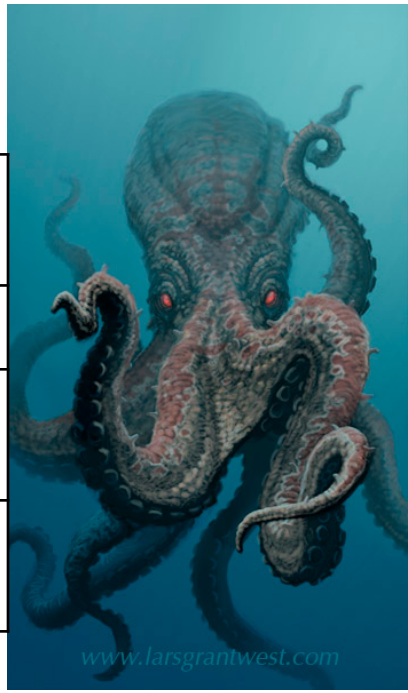
Apples and Automobiles: a decision process for an exoplanet direct detection mission (XDM)

Charley Noecker

Choosing XDM in 2015 will be unwieldy

Decision must fold together judgments on...	despite...
Science capability	incomplete knowledge of zodis and $\eta_{\oplus}$ factors of 2 in observatory size and capability
Technology readiness	inadequate and unequal technology development
Technology risk	wild guesses about how easily the remaining technology concerns will be addressed
Cost and cost risk	cost estimates (notoriously uncertain & variable) wild guesses about how much those costs may rise



It seems crazy to make such a big decision with so much uncertainty

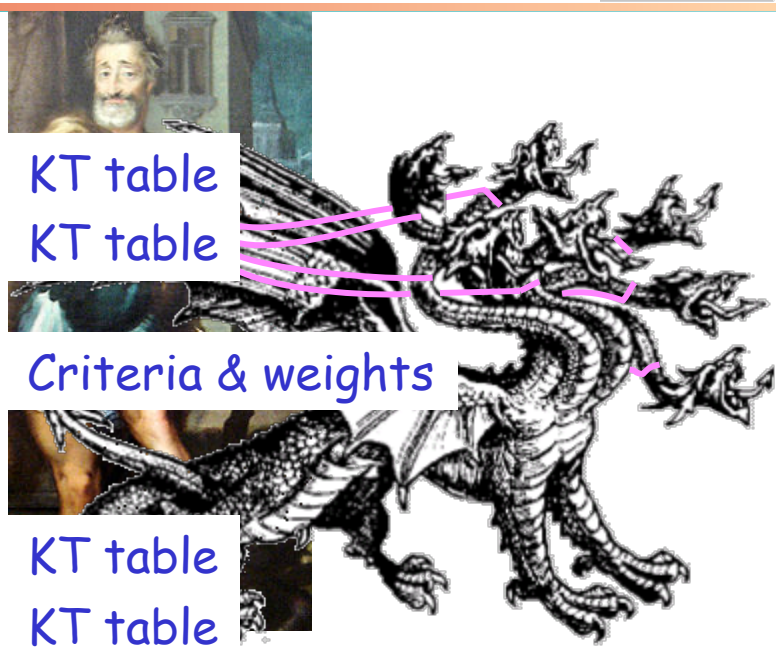
But we have only one bold shot at this mission

Must make the best decision we can

Taming the Hydra

We need a formal decision process

- It must be interdisciplinary
- It must organize multiple heterogeneous considerations, factual and subjective
- It must guide the mission concept studies (set the stage for valid comparisons) and incorporate their results
- It must handle both hard and soft reqts
- It must document the justification for the final choice
- It should be collaborative
  - Ensure the decision has multiple "parents" representing various communities
  - Discourage domination by one person (before the end)
- IT MUST BE FINAL



KT table formulation process
Senior Review Panel process

NASA selection official

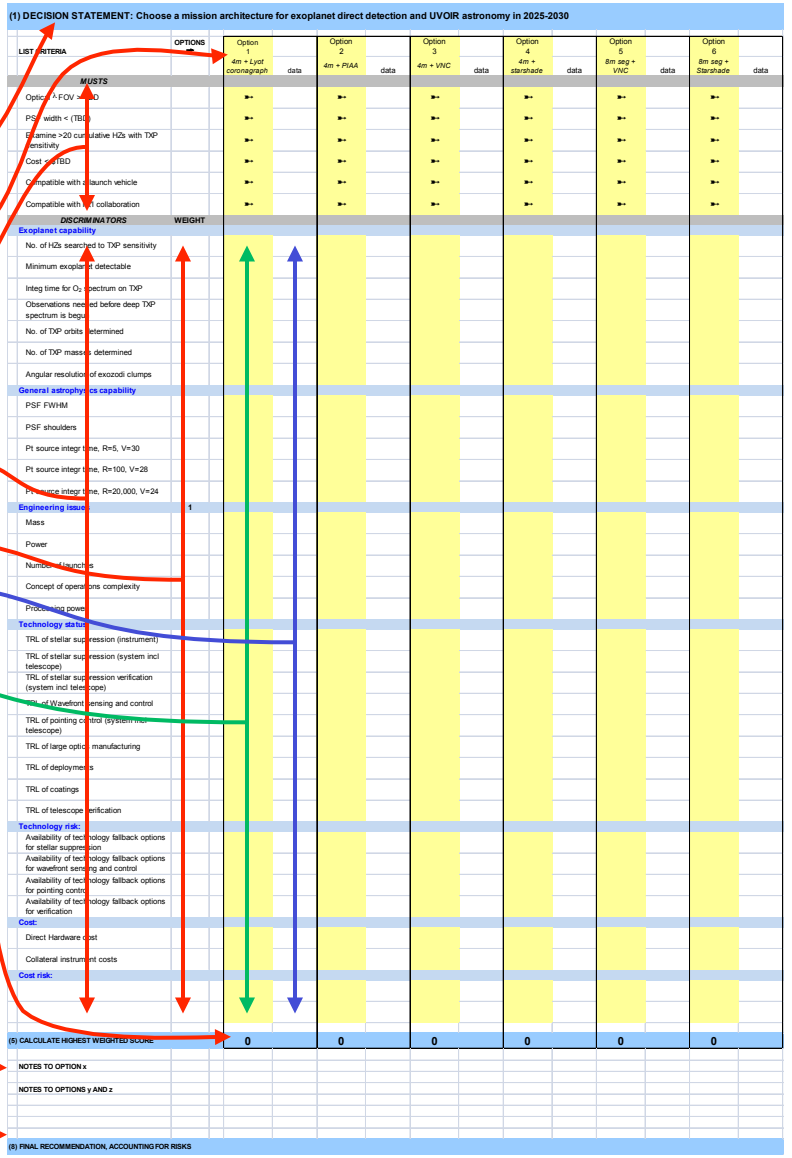
Kepner-Tregoe decision methods

- Developed for managers of all kinds, confronting decisions of all kinds
- Transferred into engineering and adapted for complex decisions
- Used for TPF-I and other JPL programs
- Organizes the entire decision process
  - Explicit, precise declaration of the question
  - Formulation of the candidates for selection
  - Development of criteria and weighting factors
  - Scoring and combination of multiple scores
  - Group dynamics for multiple participants
  - Decision table is largely self-documenting
- This process will be inherently subjective and social, but it encourages crisp thinking and discussion

- The least terrible of all possible decision methods: because it occurs openly, in a public document, in collaboration

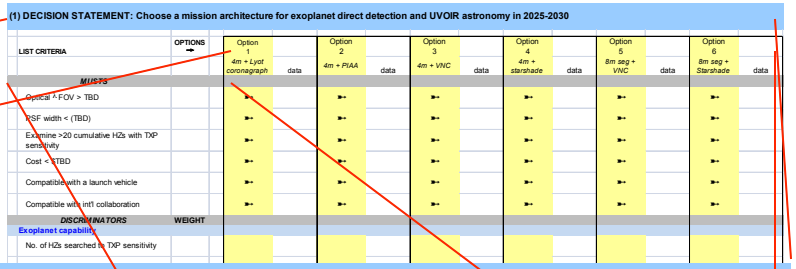
Introduction to the KT decision table

- Every detail on this page is an example or notional starting point for discussion
- Decision statement
- Options (observatories)
- Musts (pass/fail)
- Discriminators (better/worse)
- Weights (importance)
- Metrics, scores, and weighted total
- Other constraints
  - European interest?
  - Strategic issues?
- Final recommendation



Introduction to the KT decision table

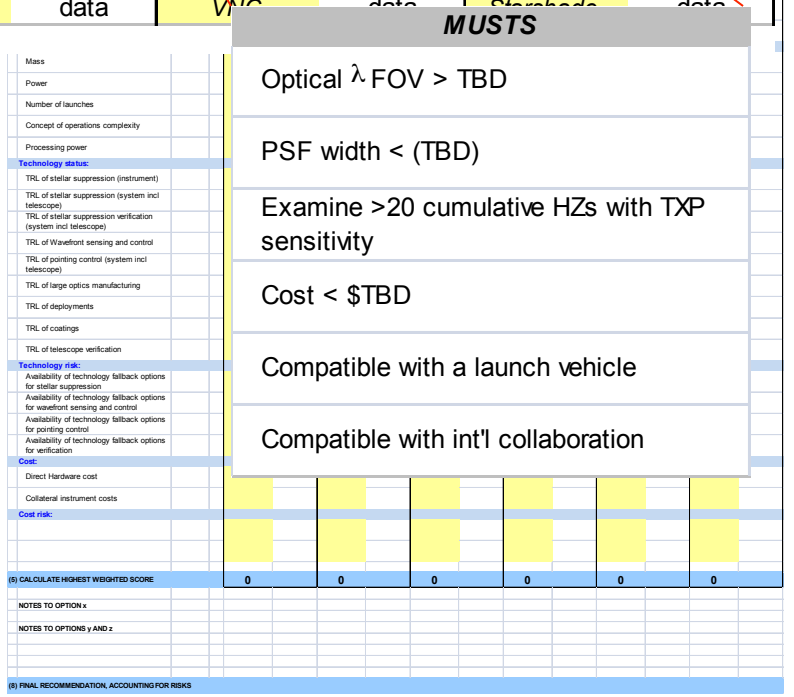
- Every detail on this page is an example or notional starting point for discussion
- Decision statement



(1) DECISION STATEMENT: Choose a mission architecture for exoplanet direct detection and UVOIR astronomy in 2025-2030

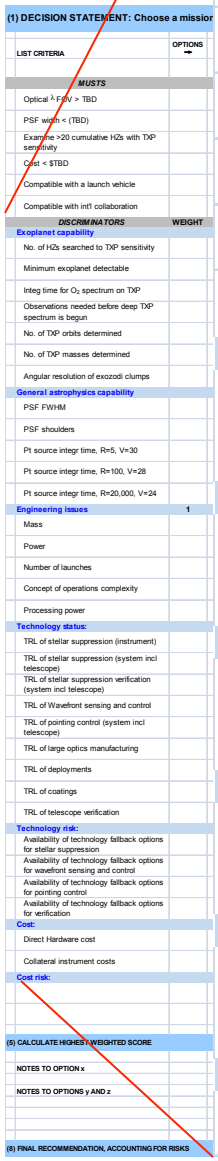
Option 1 *4m + Lyot coronagraph*	data	Option 2 *4m + PIAA*	data	Option 3 *4m + VNC*	data	Option 4 *4m + starshade*	data	Option 5 *8m seg + VNC*	data	Option 6 *8m seg + Starshade*	data

- Weights (importance)
- Metrics, scores, and weighted total
- Other constraints
  - European interest?
  - Strategic issues?
- Final recommendation



Introduction to the KT decisio

- Every detail on this page is an example or notional starting point for discussion
- Decision statement
- Options (observatories)
- Musts (pass/fail)
- Discriminators (better/worse)
- Weights (importance)
- Metrics, scores, and weighted total
- Other constraints
  - European interest?
  - Strategic issues?
- Final recommendation

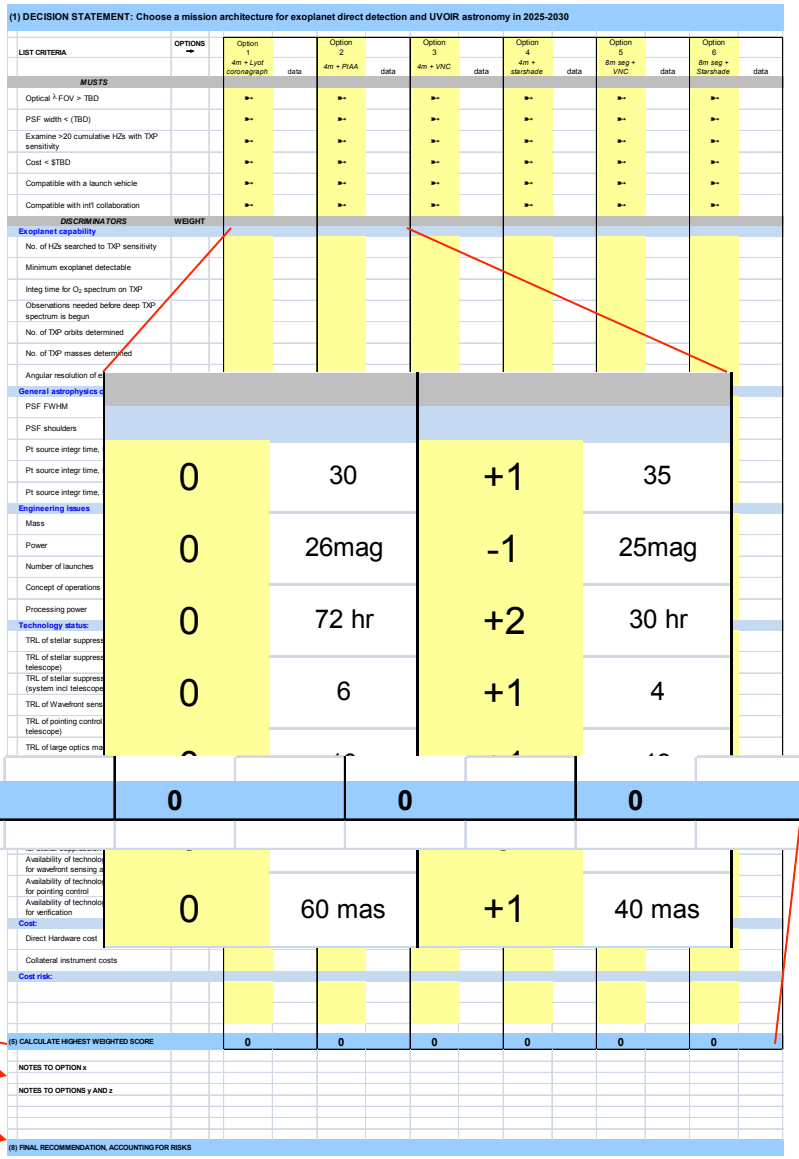

(1) DECISION STATEMENT: Choose a mission

LIST CRITERIA	OPTIONS →
MUSTS	
Optical λ-FOV > TBD	
PSF width < (TBD)	
Examine >20 cumulative HZs with TXP sensitivity	
Cost < $TBD	
Compatible with a launch vehicle	
Compatible with int'l collaboration	
DISCRIMINATORS	WEIGHT
Exoplanet capability	
No. of HZs searched to TXP sensitivity	
Minimum exoplanet detectable	
Integ time for O_2 spectrum on TXP	
Observations needed before deep TXP spectrum is begun	
No. of TXP orbits determined	
No. of TXP masses determined	
Angular resolution of exozodi clumps	
General astrophysics capability	
PSF FWHM	
PSF shoulders	
Pt source integr time, R=5, V=30	
Pt source integr time, R=100, V=28	
Pt source integr time, R=20,000, V=24	
Engineering issues	1
Mass	
Power	
Number of launches	
Concept of operations complexity	
Processing power	
Technology status:	
TRL of stellar suppression (instrument)	
TRL of stellar suppression (system incl telescope)	
TRL of stellar suppression verification (system incl telescope)	
TRL of Wavefront sensing and control	
TRL of pointing control (system incl telescope)	
TRL of large optics manufacturing	
TRL of deployments	
TRL of coatings	
TRL of telescope verification	
Technology risk:	
Availability of technology fallback options for stellar suppression	
Availability of technology fallback options for wavefront sensing and control	
Availability of technology fallback options for pointing control	
Availability of technology fallback options for verification	
Cost:	
Direct Hardware cost	
Collateral instrument costs	
Cost risk:	
(5) CALCULATE HIGHEST-WEIGHTED SCORE	
NOTES TO OPTION x	
NOTES TO OPTIONS y AND z	
(8) FINAL RECOMMENDATION, ACCOUNTING FOR RISKS	

DISCRIMINATORS	WEIGHT
Exoplanet capability	
No. of HZs searched to TXP sensitivity	**10**
Minimum exoplanet detectable	**5**
Integ time for O_2 spectrum on TXP	**5**
Observations needed before deep TXP spectrum is begun	**8**
No. of TXP orbits determined	**12**
No. of TXP masses determined	**2**
Angular resolution of exozodi clumps	**12**
General astrophysics capability	
•	
•	
•	
Engineering issues	
•	
•	
•	
Technology status:	
•	
•	
•	
Technology risk:	
•	
•	
•	
Cost:	
•	
•	
•	
Cost risk:	

Introduction to the KT decision table

- Every detail on this page is an example or notional starting point for discussion
- Decision statement
- Options (observatories)
- Musts (pass/fail)
- Discriminators (better/worse)
- Weights (importance)
- Metrics, scores, and weighted total
- Other constraints
  - European interest?
- Final recommendation



(5) CALCULATE HIGHEST WEIGHTED SCORE 0 47 0 0 0 0

Options

- Each "Option" is mission concept —an assembly of characteristics chosen by the community, especially its advocates
  - Internal or external occulter, IWA, telescope size, obscuration, stability, other requirements
- Community must choose a fair organizing principle for generating combinations of these characteristics & designating them as Options
  - e.g. a 4m and an 8m telescope for internal/external occulters, or science benchmarks, or cost benchmarks
- More Options is better at first; premature or haphazard whittling causes unfairness
- List must be whittled to ~4 before SWGs undertake detailed studies
  - e.g. small and large for each type of planet-finder
  - Naturally should be done by advocates in a way that ensures fairness compared to other Options

Discriminators, weights, and scores

- Discriminators are key differences that are important to the mission
  - A place to give credit for an advantage, or subtract for a disadvantage
  - List should include anything that could have an impact on mission success
  - Should be linked to well-defined metrics as much as possible
- Weights are a judgment of their relative importance
  - Developed by debate among the community (ExoPAG, COPAG, et. al.)
  - "Where the rubber hits the road" — this will dominate the decision, and guide the efforts of SWGs in tailoring their concepts
  - Overlap and duplication among Discriminators gives hidden extra weighting (to be avoided)
- Scores are the judgments of relative merit w.r.t. those metrics
  - For simplicity, usually an integer between -2 and +2
  - Related monotonically to metric values by an agreed lookup table for each discriminator
  - First "Option" is the reference, and thus assigned all zeros
- Weighted total is usually sum(weight*score) down each column

The End Game

- There is a temptation to "game the system" at the end — adjust scores and weights to turn an opinion into a decision
- Normally, this is explicitly acknowledged and even encouraged
  - The results of evaluating metrics and tallying scores will teach you about the Options and their strengths and weaknesses
  - Participants in the decision aim to arrive at a consensus: everyone understands why the selected Option is winning, and everyone accepts the reasoning
  - Adjustments allow an exploration of the sensitivity to minor tweaks
- In this case, we probably do not allow this much freedom in the end
  - Advocates for one Option may want to change their minds about the ground rules when they see the outcome
  - Senior Panel members may not have the standing (depth of knowledge or technical authority) to countermand the judgment of the community
  - Instead just report on sensitivity to assumptions and tweaks

Who does what

- The community (us) will set up the decision
  - Defining Options
  - Defining Musts and Discriminators, assigning weights
- The Senior Review panel will execute the decision
  - Assembling metric values
  - Assigning scores to go with those values
  - Iterating scores to distill a decision from the mud
  - Adjusting weights only with concurrence from HQ and key members of the community (us)
- NASA official reviews the recommendation and decides

The Final Risk

- After the decision is made in 2015, we still must make the observatory look easy by 2020
  - There is no guarantee that any decision (by any process) will yield a workable mission concept
- We must aim for the most robust choice in 2015, not necessarily the best

- My main concerns with the plan are
  - that we won't have enough time and money to get the most important answers to make a robust choice
  - that there will be a gap of 3+ years in technology development during the decision period 2014-16